Unit Four

Chapter 1



Thermochemistry

Part (1): Thermochemistry

Basic concepts of thermodynamics

- Energy is important for all living organisms to carry out their mental or muscular activities.
- Living organisms can get their energy from burning sugar inside their bodies.
- Heat energy is a form of energy that can be obtained from burning of natural gas.

Thermodynamics:

The science that deals with the study of energy and how it transfers.

Thermochemistry:

Branch of chemistry that studies the heat effects that accompanied the chemical reactions.

- There are different forms of energy as (heat , light , electric, kinetic, ….) , all these forms are related to each other by law of conservation of energy.

Law of conservation of energy:

Energy in any physical or chemical change can be neither created nor destroyed but it is transformed from one form to another.

What is the relation between chemical reaction and energy:

-All chemical reactions is associated with changing in energy either release or absorb energy

-Energy exchange occurs between reaction mixture and surrounding.

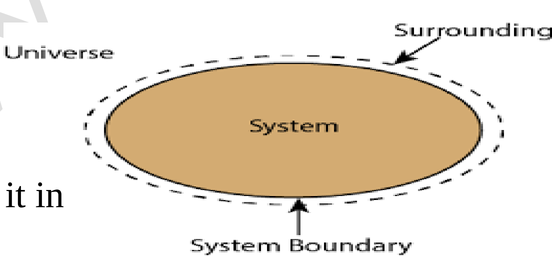
System:

It is the part of the substance under study.

It is the part of the universe in which physical or chemical change occurs.

Surrounding:

It is the part outside the system and exchange energy with it in the form of heat or work.



Types of systems:

Isolated system	Open system	Closed system
It does not exchange neither energy or matter with its surroundings.	It freely exchange matter and energy with its surroundings.	It exchange energy but not matter with its surroundings in the form of heat or work.

►**The medical thermometer is considered as a closed system.(G.R)**
Because it allows the exchange of energy only with the surrounding.

First law of thermodynamics:
The total energy of an isolated system is constant even the system is changed from one state to another.

-The relation of energy exchange between the system and surrounding

Universe = System + Surrounding

-Change in universe energy = Change in system energy + Change in surrounding energy

$$\triangle E_{universe} = \triangle E_{System} + \triangle E_{surrounding}$$

- Any change in system energy is accompanied by similar change in the surrounding energy but with opposite sign to keep the total energy constant

$$\triangle E_{system} = -\triangle E_{surrounding}$$

Heat and temperature:

Heat flow from one position to another depending on the difference in temperature between the two positions.

Temperature:

It is indication of hotness or coldness of an object.

Or It is measurement of the average kinetic energy of matter molecules.

-Matter consists of molecules or atoms , they are in continuous motion but they differ in speed according to their kinetic energy.

- When the system absorbs heat energy, kinetic energy increase the temperature increase.

Measuring units of quantity of heat:

Calorie	Joule
It is the quantity of heat needed to raise the temperature of 1 g of water by 1^{o} C	**It is the quantity of heat needed to raise the temperature of 1 g of water by $\frac{1}{4.18}$ ^{o} C**

Specific heat:

The quantity of heat needed to raise the temperature of one gram of the substance 1^{0} C.

Unit: $J/g^{0}C$

- Each substance has definite specific heat .
- The substance that has high specific heat need large quantity of heat to rise its temperature and also takes a long time to lose this heat again.
  - Water has the highest specific heat.

❖ **Water causes a moderate climate in a coastal areas.(G.R)**

Because it has high specific heat.

Calculating the quantity of heat:

The quantity of heat absorbed or released from the system calculated by this relation.

$q_p = m.c. \triangle T$

q_p The quantity of heat at constant pressure.(joule)

m The mass of substance(g)

c The specific heat($J/g.^0C$)

$\triangle T = T_2 - T_1$ (final temperature – initial temperature) (^0C)

Example:

Using the calorimeter, 0.28 g of propanol was burned. The temperature of water increased by 21.5 ^0C if you knew that the mass of water in the calorimeter is 100 g , calculate the released quantity of heat from the burning of this amount of fuel.

Answer:

$q_p = m.c. \triangle T$

$= 100 \times 4.18 \times 21.5$

$=9030$ J

Example:

Dissolve one mole of ammonium nitrates in an amount of water. Complete the solution volume to 100 ml of water. You notice that the temperature decreases from 25^0C to 17^0C calculate the quantity of absorbed heat.

Answer:

The mass of 100 ml water is

100 g $q_p = m.c.\triangle T$

$q = 100 \times 4.18 \times (17 - 25) = -3344$ J

The calorimeter:

It is an isolated system that allows us to measure the change in temperature of isolated system because it prevents lose or gain of heat or substance to the surroundings.

Types of calorimeter:

	Coffee – cup calorimeter	Bomb Calorimeter
Structure	-Isolated container -Stirrer -Thermometer -Reactants	-Isolated container -Stirrer -Thermometer -Reactants -Ignition wires
Use	Measure the change in temperature	Measure the heat of combustion
Shape		
Note	Water is used in both types of Calorimeter. Why? Because it has high specific heat	

Chapter 1

Part 1



❖ Write the specific term:

1-Energy can be neither created nor destroyed. (………………………………..)

2-A part of the universe in which physical or chemical change occur. (……………..……………)

3-A system does not exchange either energy or matter with its surrounding. (……………..……………)

4-The total energy of an isolated system is constant (……………..……………)

5-The quantity of heat required to raise the temperature of 1 g of water by 10C. (……………..……………)

6-The quantity of heat required to raise the temperature of 1 g of water by 1 /4.180C (…………………………….)

7-The quantity of heat required to raise the temperature of 1 g of substance by 10C. (……………..……………)

8-An isolated system used to measure the heat of combustion of some compounds (………………………….)

❖ Choose the correct answer:

1-All the physical and chemical changes accompanied with a change in………..

a)color b) mass .... c) energy d) density

2- Calorie = joule

a) 2.18 b) 3.18 c) 4.18 d) 5.18

3-The temperature of a substance is doubled, its specific heat will be………

a) decrease to half b)constant

c)increase to double d)increase to four times 4-4-4-4-4—

4-Thermometer is considered as................................ system

a)open b)closed d)isolated d)no correct answer

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❖ Give reason for:

1-The medical thermometer is a closed system

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2-Water is used in calorimeter.

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❖ Problems:

1-Calculate the quantity of heat required to raise the temperature of 50 cm3 of water from 30o C to 50o C expressed in joule (Cs of water is 4.184 J/g.oC).

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2-A piece of copper its mass is 400 g absorbed a quantity of heat equals 9360 J and its temperature raised from 200C TO 800C. What is the specific heat of copper?

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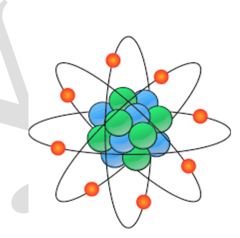
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Part (2): Heat Content

Heat content:

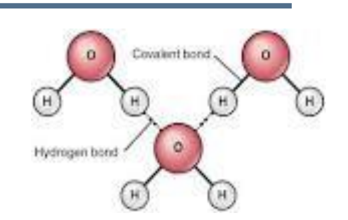
-Each chemical substance has a different number and type of atoms and different type of bonds between its atoms so it has a specific amount of energy called internal energy.

-The internal energy of a chemical substance is the summation of energies stored in it.



1-Stored chemical energy in the atom	Is represented in the energy of electrons in the energy level Energy of electron = kinetic energy + potential energy.
2-Stored chemical energy in the molecule	It is the energy of chemical bonds between its atoms ionic or covalent.
3-Intermolecular forces	The attraction force between molecules is called **Van der Waals force**
4-Hydrogen bond	If the compound is polar and has hydrogen in its structure.

- The summation of these energies are called **Heat content**



Heat content of a substance (molar enthalpy) H:

The sum of the stored energy in one mole of a substance.

- Heat content for the element = zero

Heat content change (ΔH):

The difference between the sum of the heat content of the products and the sum of the heat content of the reacting substances.

Heat content = Heat content of products – Heat content of reactants

$$\triangle H = \sum H_{Products} - \sum H_{reactants}$$

Standard heat content $\triangle H^0$ $H^0 = \frac{q}{n}$

Comparison of values of different reactions under standard conditions

-Pressure = 1 atm

-Temperature = 25^0C

-Solution concentration 1 M

Thermo chemical equation

It is a symbolic chemical equation that includes the heat change accompanying the chemical reaction and this heat change is represented in the equation as one of the reactants or products.

Example: Calculate the change in heat content $\triangle$ H resulted from the decomposition of 136 g of ammonia gas under constant pressure to give hydrogen and nitrogen gases.

$$2NH_3 \longrightarrow N_2 + 3H_2 \qquad \triangle H = 92.2\ kJ$$

Answer:

Molar mass of NH_3 = 14 + (3x1) = 17 g/mol

No. of moles of NH_3 = $\frac{136}{17}$ = 8 mol

From the equation:

2mol of ammonia…............................... 92.2 KJ

8mol .... ??

$\triangle$H=368.8KJ

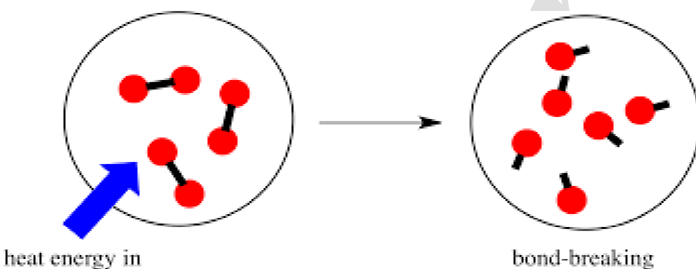
Types of chemical reactions:

Exothermic reactions	Endothermic reactions
Release energy	**Absorb energy**
Heat transfer from the system to the surrounding	**Heat transfer from the surrounding to the System.**
Heat content of product less than reactants	**Heat content of reactant less than the product**
H negative	**H positive**
H_{prod}> H_{react}	**H_{prod} <H_{react}**

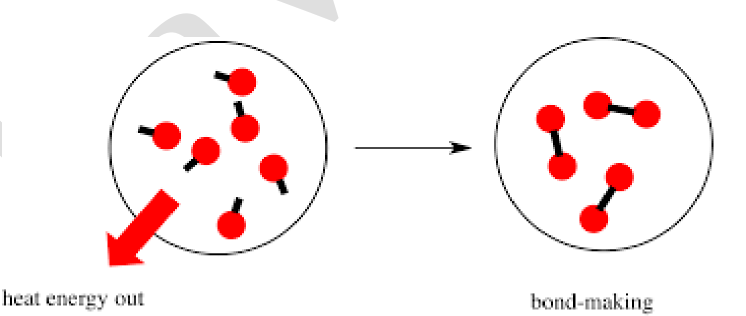
Bond energy:

It is the amount of energy absorbed to break the bonds or released during formation of bonds in one mole of the substance.

-Breaking bonds is endothermic reaction(absorb energy from the surrounding)



-Formation of bonds is exothermic reaction (energy of the surrounding increases)



- Energy must be absorbed to break the bond or energy released when the bond is formed in one mole of the substances

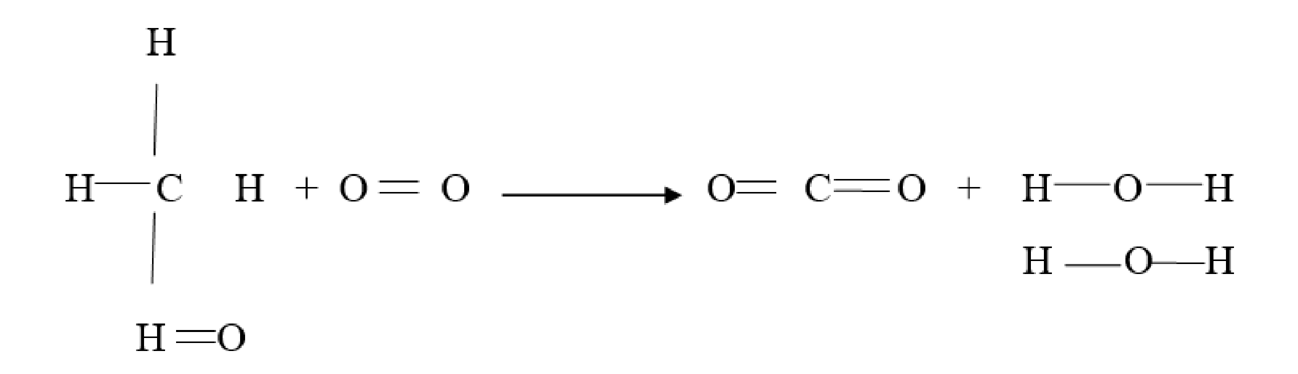
Example:

Calculate the heat of the following reaction and determine if the reaction is exothermic or endothermic.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Knowing that the bond energy is estimated by the unit (KJ/mol) as follows

(C ═ O)745, (O – H) 467, (C ═ H) 413 , (O O)498



The energy required to break reactant bonds = [4 × (C – H)] + [2 × (O ═ O)]

=[4 × 413] + [2 × 498]=2648 KJ

The energy released from formation of bonds in the products = [2 × (C═O)] +[2 × 2(O—H)]

=[2 × 745] + [2×2×467]=3358KJ

△H = (PRODUCT + REACTION)

= (-3358) +2648 = -710 KJ

The reaction is exothermic because △ H is negative.

m

Chapter 1
Part 2



❖ Write the specific term:

1. The sum of stored energy in one mole of a substance. (…………………….)
2. The chemical reaction in which the heat transferred from the surrounding to the system. (……………………..)
3. An energy must be absorbed to break the bond in one mole of the substance (………………………..)

1. Choose the correct answer:

2. The formation of bond is .... process.

a)releasing energy b) exothermic c) endothermic d) a & b are correct

3. If the heat content of products is lower than that of reactants, thus the reaction……

a) endothermic b)exothermic
c)its Δ H value has a positive sign d)whose Δ H value = zero

❖ Give reason for:

1- ΔH value of exothermic reactions has a negative sign.

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2-The chemical reaction is accompanied with change in heat content
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❖ Problems:

1-Calculate the change in heat content for the following reaction. $CH_4 + 3 Cl_2 \longrightarrow CHCl_3 + 3HCl$

Where the heat content of CH4= -74.85 KJ/mol , CH3Cl = -132 KJ/mol , HCl = -92.3 KJ/mol

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2-Calculate the molar enthalpy for water vapor from the following reaction

$CH_4 + H_2O \longrightarrow CH_3OH + H_2 \quad \triangle H = -78$ KJ/mol

The molar enthalpy for $CH_4$and CH_3OH are 75 KJ/mol, 293 KJ/mol respectively Then calculate the absorbed heat when 64 g of CH_4 reacts with excess of water

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3-Draw the energy graph of the following reaction

$H_2 + 1/2\, O_2 \longrightarrow H_2O \quad \triangle H = -285.8$ KJ/mol

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4- Calculate the change in enthalpy in the following reaction

$C_2H_2 + 5/2\, O_2 \longrightarrow 2CO_2 + H_2O$

Where the bond energy of

(C – H) =413 KJ/mol , (C ═ C) = 835 KJ/mol

(O – H) = 467 KJ/mol , (C ═ O) =803 KJ/mol , (O ═ O) =498 KJ/mol

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Unit Four

Chapter 2

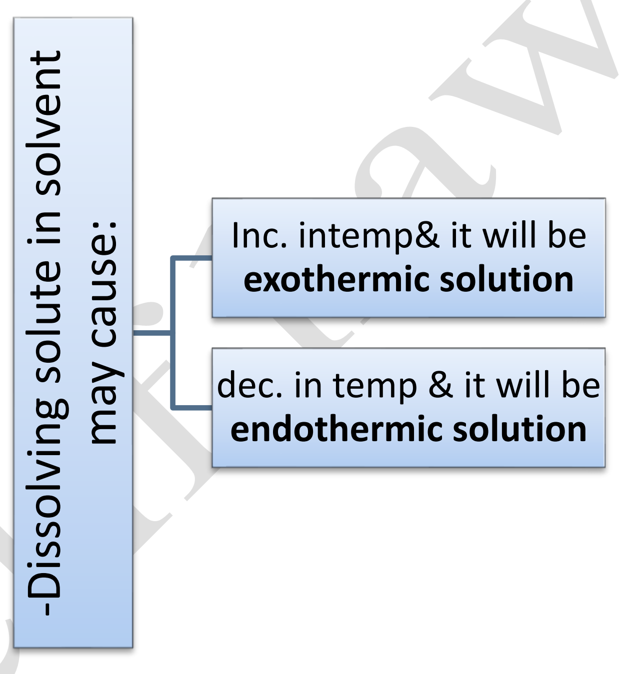


Forms of change in heat content

1- Standard heat of solution $\triangle H^0_{sol}$
2- Standard heat of dilution $\triangle H^0_{dil}$

1- Standard heat of solution $\triangle H^0_{sol}$

It is quantity of heat absorbed or released on dissolving one mole of solute in certain amount of solvent to obtain standard solution in standard conditions.



- Calculate heat of solution

$q=m.c_s.\triangle T$

m------mass = Volume in mL
Bec. Density of water 1g/cm^3

C_s------ Specific heat of water = 4.18 J/g.^{o}C
If volume = 1L it is called molar heat of solution

Molar heat of solution:

The heat changes on dissolving one mole of solute to form one liter of solution.

$$\text{Molar heat of solution} = \frac{\text{amount of heat}}{\text{numbers of moles}} \qquad \triangle H = \frac{q}{n}$$

Example:

By dissolving 1mol of sulphuric acid in an amount of water to produce a solution of 1000 ml volume, the temperature increases by 170C. Calculate the amount of released energy

$q = m . c_s . \triangle T$

$= 1000 \times 4.18 \times 17 = 71060 \text{ J}$

What is the source of heat of solution??

1- Separating solvent molecules from each other

$\triangle H_1$ need energy ⟶ endothermic process +ve value

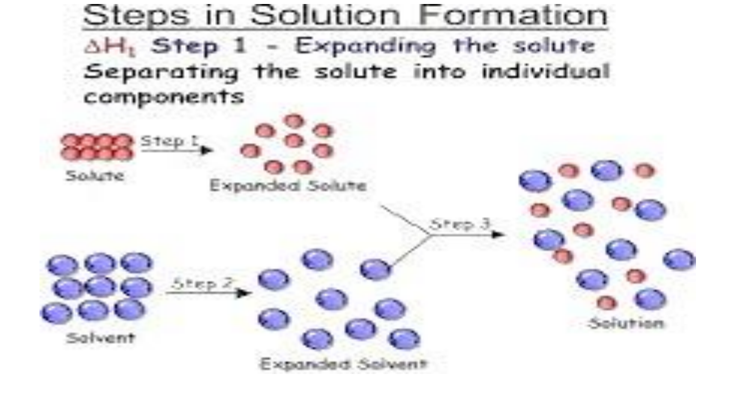
2- Separating solvent molecules from each other

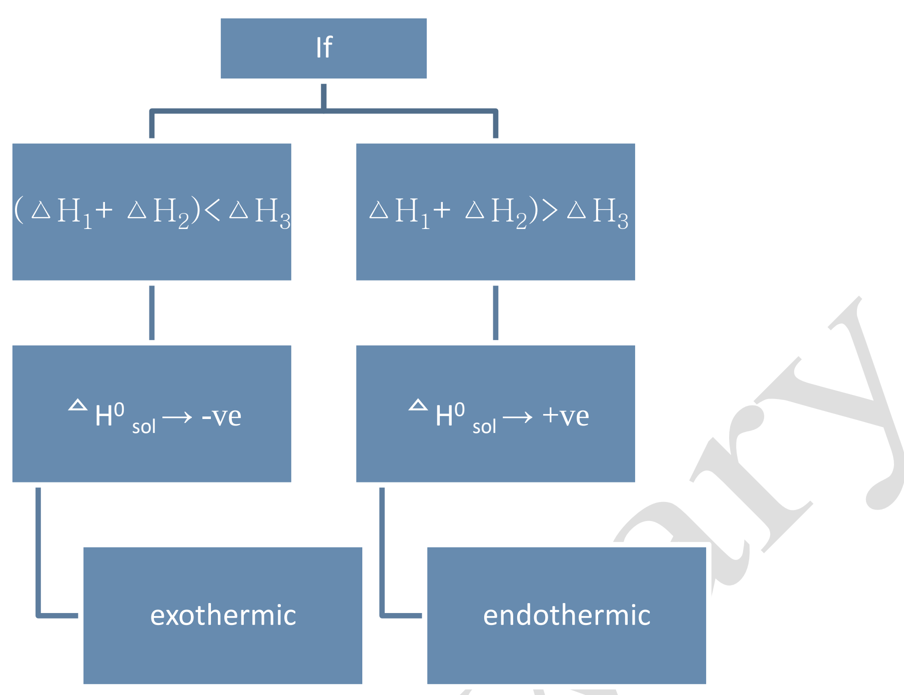
$\triangle H_2$ need energy ⟶ endothermic process +ve value

3- Dissolving process (attaching solute and solvents molecules)

$\triangle H_3$ need energy ⟶ endothermic process +ve value

$\triangle H^0_{sol} = \triangle H_1 + \triangle H_2 + \triangle H_3$





If the solvent is water, dissolving process is called hydration

Hydration:
attaching of dissociated ions with water.

2- Standard heat of dilution $\triangle H^0_{dil}$

It is the quantity of heat released or absorbed for each one mole of solute when diluting the solution from high concentration to low concentration in standard state.

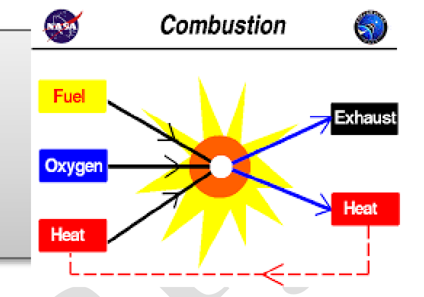
Dilution process occurs in two processes:

1-Separating process (separate solute from each other)
need energy $\longrightarrow$ endothermic
2-Attaching process (attaching solute to solvent)
Release energy $\longrightarrow$ exothermic

Heat changes accompanying chemical changes

1-Standard heat of combustion
2- Standard heat of formation

Combustion:
Combination between the substance and oxygen.



Heat of combustion: △ Hc
Quantity of heat released when one mole of substance completely burned in excess amount of oxygen

Standard heat of combustion: △ H^o_C
Quantity of heat released when one mole of substance completely burned in excess amount of oxygen at standard conditions.

Examples:

Burning of fuel – burning of glucose inside body.

Notes:

- All combustion reaction release energy ⟶ exothermic
(△H is always negative value)

- Any combustion produces CO_2 & H_2O

Heat of formation: $\triangle H_f$:

Quantity of heat absorbed or released during formation of one mole of compound from its elements.

Standard heat of formation: $\triangle H^o_f$:

Quantity of heat released or absorbed during formation of one mole of compound from its elements in standard conditions.

-Heat formation of element = zero

$\triangle$ H = sum of heat formation of products – Sum of heat formation of reactants

Example:

Calculate the change in the heat content of the following reaction:

$$CH + 2\,O_2 \longrightarrow CO_2 + 2H_2O$$

By knowing that $\triangle H^o_f$ of CH_4, CO_2 and H_2O is **(-74.6 , - 393.5 , -241.8 KJ /mol) in order**

$\triangle H = \triangle H_P - \triangle H_R$

$= [(-393.5 + (2 \times -241.8)] - [(-74.6) + (0)]$

$= -802.5$ KJ/mol

Relation between heat of formation and stability of the compound.

Stable compound	Unstable compound
-Heat content of product smaller than reactant -exothermic compounds H has -ve value	-Heat content of product larger than reactant -endothermic compounds H has +ve value

Hess's law:

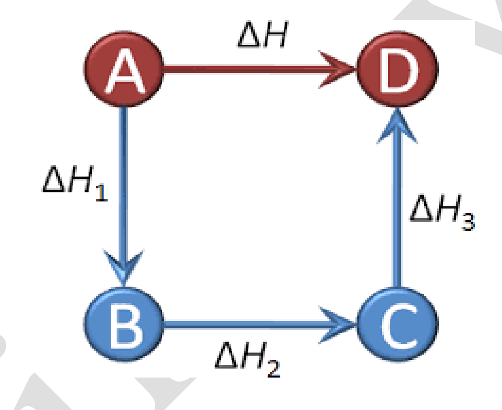
Heat of reaction is constant amount in standard conditions, whether the reaction is carried out in one step or a number of steps.

It is used to calculate heat of reactions such as

1-very slow reactions as rust

2-Dangerous reactions

3-Some reactions that their heat changes is difficult to measure.



Chapter 2



❖ Write the specific term:

1. Combination of the dissolved ion with water. (… ....)
2. The change in heat content resulting from dissolving 1 mol of solute in one liter of solution. (… ....)
3. The quantity of released or absorbed heat for each one mole when diluting the solution from a high concentration to another lower concentration in standard condition. (…......................................)
4. Combination between the substance and oxygen accompanying with releasing an amount of energy as light or heat. (… ....)
5. The heat change accompanying the formation of the compound from its constituent elements. (… ....)

❖ Choose the correct answer:

1- Dilution process is accompanied with…………………

a) releasing heat   b) absorbing heat

c) releasing or absorbing heat   d) no heat change

2-The stability of compound.............................by increasing its heat content.

a) increase   b) decrease   c)doesn't change   d)is constant

3-Most reactions move in the direction of the formation of……..compounds.

a) endothermic   b)less stable   c)more stable   d)higher heat content

❖ Give reason for:

1-Dissolving sodium hydroxide in water is accompanied with rising in solution temperature.

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2-Ion separating energy for a solute has a positive sign.

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3-There is a relation between the stability of compounds and heat of formation.

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❖ Problems:

1- Calculate Δ H for the following reaction

$S + O_2 \longrightarrow SO_2$ by using the following thermo chemical equation

(1) $2SO_2 + O_2 \longrightarrow 2SO_3$ $\Delta H_1 = -196$ KJ/mol

(2) $2S + 3O_2 \longrightarrow 2SO_3$ $\Delta H_2 = -790$ KJ/mol

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2- Calculate the heat of combustion of nitric oxide gas NO, according to the following equation.

$NO + \frac{1}{2} O_2 \longrightarrow NO_2$ By using the following thermo chemical equation

(3) $\frac{1}{2}N_2 + \frac{1}{2}O_2 \longrightarrow NO$ $\Delta H_1 = +90.29$ KJ/mol

(4) $\frac{1}{2}N_2 + O_2 \longrightarrow NO_2$ $\Delta H_2 = +33.2$ KJ/mol

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3- If the heat of formation of methane is -74.6 kJ/mol, that of carbon is -393.5 KJ/mol and that of water is -24.8 KJ/mol, calculate the change in the heat content of the reaction shown in the following equation

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

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Unit Five

Chapter 1

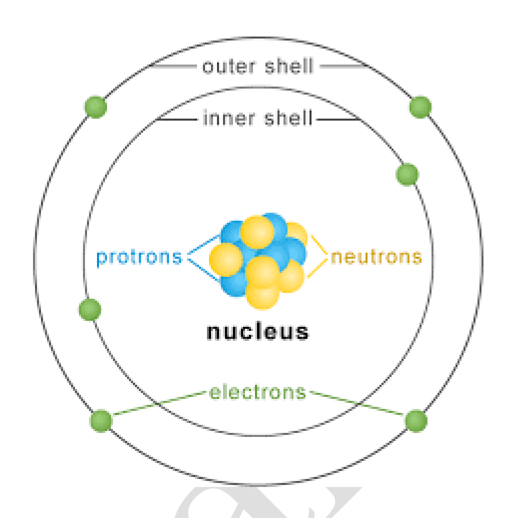
Nuclear Chemistry


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Atom components: Atom contain three particles.



Proton

- Positive charged
- in the nucleus
- has large mass = 1800 times mass of election

Neutrons

- Neutral charged
- in the nucleus
- it is mass nearly equal proton mass

Electrons

- Negative change
- around nucleus in energy levels
- neglected mass

Atom is neutral charged. Why ?

Bec. No. of negative electrons equal no. of + ve protons

Mass of atom concentrated in nucleus .Why ?

Bec. It contain protons & neutrons while mass of electrons is negligible

Atomic number: number of proton or electrons.

Mass number: number of protons and neutrons.

No of neutrons = mass number – atomic number

Isotopes:

Atoms of some elements have same atomic number and different in mass number due to difference in number of neutrons.

Isotopes have same chemical properties. Why ?

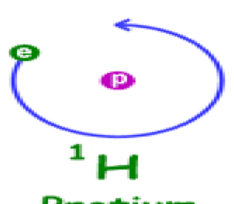
Bec. They have the same number of electrons.

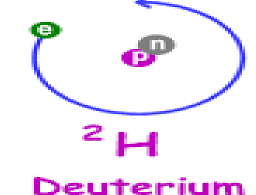
Example :

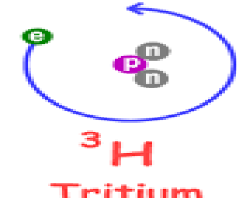
isotopes of hydrogen.

P.O.C	Protium	Deutrium	Tritium
Symbol	$^{1}_{1}H$	$^{2}_{1}H$	$^{3}_{1}H$
Atomic no.	1	1	1
Mass no.	1	2	3
Neutron	1 – 1 = 0	2 – 1 = 1	3 – 1 = 2

Three Isotopes of Hydrogen







Mass of isotopes: Measured in atomic mass unit

a.m.u or u

$u = 1.66 \times 10^{-27}$ Kg

Relation between mass and energy

E = m.C2

E = energy (joule)

m= mass (Kg)

C ------------ Speed of light=(3 × 108 m/s)

Units of energy:

Joule (J)
Electronvolt(ev)
Million electron volt (Mev)

$1ev = 1.602 \times 10^{-19}J$ $1Mev = 10^{6}ev$ $1Mev = 1.602 \times 10^{-13}J$

Atomic models

Ruther ford atomic model

- Heavy nucleus in center with positive charge.
- Electrons revolve around nucleus

Bohr atomic model

- Negative charged electrons rotate around nucleus in fixed orbits called energy levels

Protons & neutrons called nucleons

Forces in nature

Four main kinds

Strong nuclear force > Electromagnetic force > Weak nucleate force > Gravitation force.

Nuclear force:

Force that bind nucleons with each other.

Prop. Of nuclear force:

- ✓ Great force
- ✓ Short range force
- ✓ Doesn't depend on type of nucleons may be between (proton – proton) , (proton – neutron) (neutron – neutron)

Source of nuclear binding energy

Actual mass of nucleons is smaller than theoretical mass ?

Bec. Diff. in energy is converted into binding energy.

B.E = mass defect($\triangle$ m) × 931

$\triangle$ m = theoretical Mass – actual mass

B.E = [(Zm_p + Nm_n) - M_x] × 931

Z------atomic no. m_p ------ mass of proton

N------no of neutron ` m_n -------- mass of neutron

B.E per nucleon = $\frac{B.E}{A}$

A-------- mass number

Calculate

the binding energy in the nucleus of helium atom 24He Actual mass = 4.00150 u , mass of proton = 1.00728 u and the mass of neutron =1.00866u

B.E = [(Zmp + Nmn) - Mx] × 931
= [(2 × 1.00728) + (2 × 1.00866) – 4.00150] × 931 = 28.28378 MeV

Unit Five

Chapter 2

Radio Activity

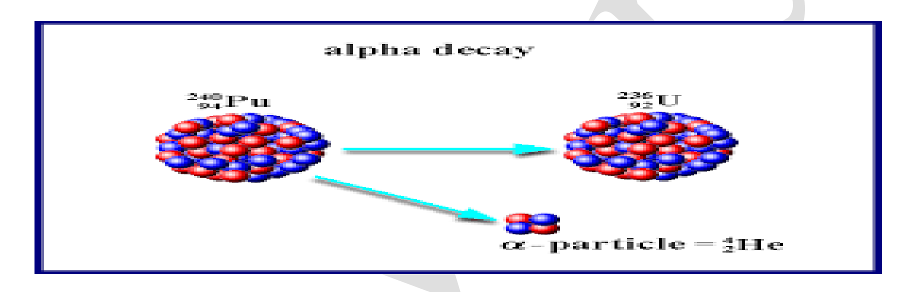
Radio active elements may emit α – β –

	Alpha	βeta	Gamma
Symbol	α	β	
Nature of radiation	$^{4}_{2}He$ Helium nucleus 2 proton & 2 neutron	$^{o}_{-1}e$ electron	Electromagnetic waves
Mass	Four time proton mass	$\frac{1}{1800}$ of proton mass	No mass as it is wave
Ability to ionize medium	strong	Less than alpha	Least power
Ability to permeate	Weak cannot pass through thin paper	Average 5mm aluminum slice prevent passing.	High pass through lead slice with thickness few centimeters.
Deviation in magnetic or electric filed	Small deviation	Large deviation	Doesn't deviate

Emitting α:

decrease atomic no. by 2 & mass no. by 4

$$_{92}^{238}U \longrightarrow _{90}^{234}Th + _{2}^{4}He$$



Emitting β:

increase atomic no. by 1

$$_{6}^{12}C \longrightarrow _{7}^{14}N + _{-1}^{0}e$$

Emitting gamma ray:

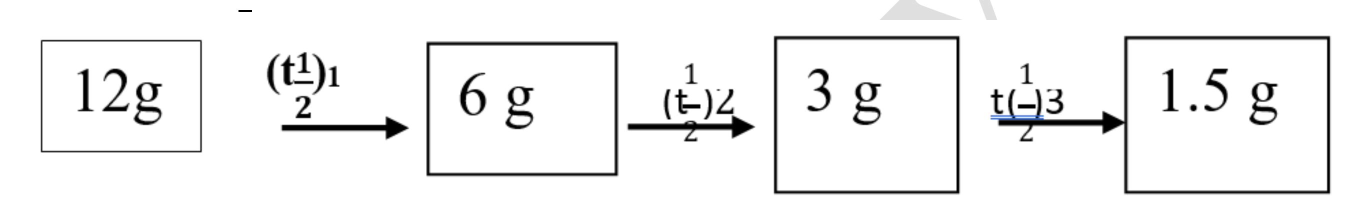
cause no change in atomic or mass number because it is a wave.

Half life time (t1/2)

It is the time required to disintegrate half the original number of atom nuclei of a Radio active element.

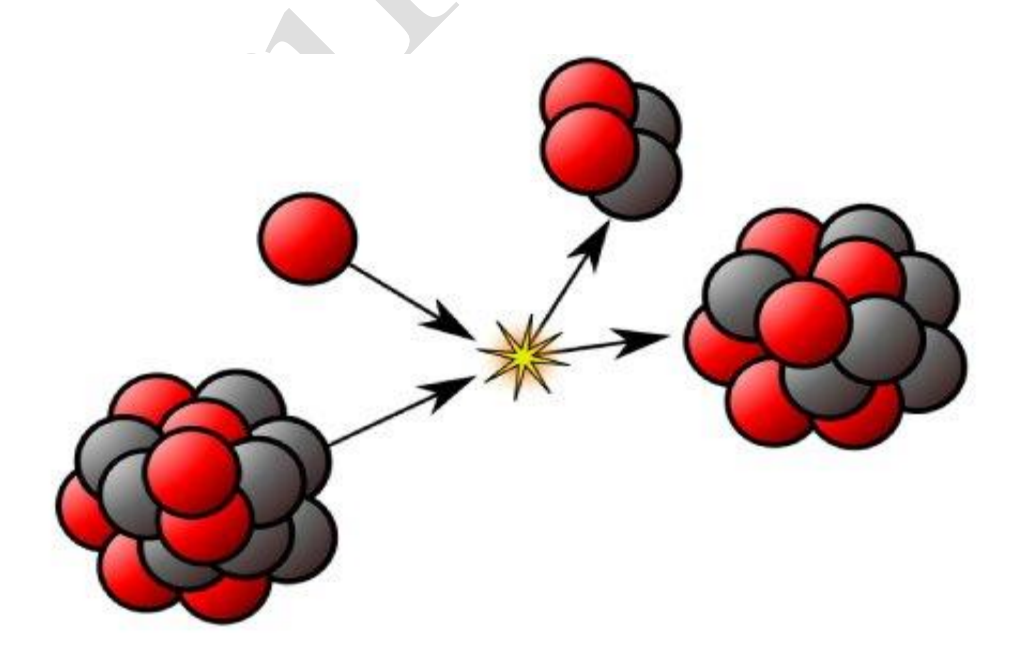
Example:

Calculate the half life time of a radioactive element , knowing that a sample of 12 g of it converted to 1.5 g after passing 45 days



Number of periods (D) =3

$t_{\frac{1}{2}}$ = t/D = 45 / 3 = 15 days



The difference between chemical reactions and nuclear reactions

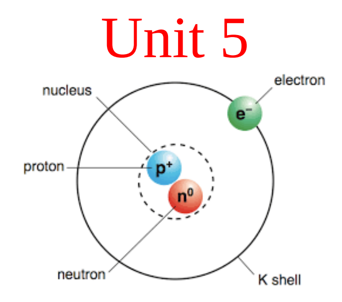
Chemical reactions

- Occur between the electrons of outermost level of the atom
- There is no transformation of an element to another
- The products are the same if we used different isotopes of the same Element
- Produce small amount of energy

Nuclear reactions

- Occurs between the nuclei of the atoms
- Almost there is transformation of an element to another or its isotope
- Isotopes of the same element give different products
- Produce large amount of energy

Unit 5



❖ Write the scientific term:

1-Particles with a very small mass and have a negative charge (………………………………)

2-The number of protons inside the nucleus. (………………………………)

3-Sum of the number of neutrons and protons inside the atom nucleus. (………………………………)

4-Particles which emitted from the nucleus of a radioactive element leads to forming a new element with an atomic number increase by one. (………………………………)

5-Electromagnetic waves when emitted from the nucleus of a radioactive element don't cause a change in its atomic and mass number. (… ....)

6-The time required to decrease the number of nuclei of the radioactive element to its half number. (………………………………)

❖ Choose the correct answer:

1-The mass of atom is concentrated in the…………………

a) nucleus b) protons c) neutrons d) electrons

2-The scientist.................... discovered that atom's nucleus contains protons

a) Bohr b) Einstein c) Nevil sidgwik d) Rutherford

3-Mass of proton is larger than the mass of electron by.............times

a) 4×10^{-15} b) 931 c)1800 d) 3×10^{8}

❖ Give reasons for:

1-The atom is electrically neutral

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2-The mass of the atom is concentrated in the nucleus.

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❖ Problems:

1- Calculate the binding energy of deuterium in MeV. Actual mass of deuterium $_1^2H$=2.014102 u , mass of proton = 1.00728 u and mass of neutron = 1.00866 u

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2-Calculate the half life of 32 g of a radioactive element, if the mass remained after 100 days is 1 g.

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3-12 g of a radioactive element stored in a safe place and remained mass after 50 days is 0.75 g calculate the half life time.

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